

Extending Automerge: Undo and Redo

Leo Stewen, Martin Kleppmann

October, 2023

(1a)



Figure 1: Canvas with two replicated registers.

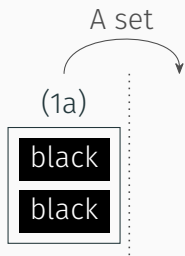


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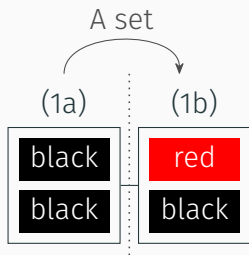


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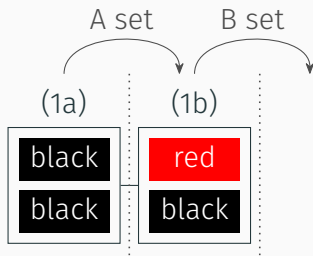


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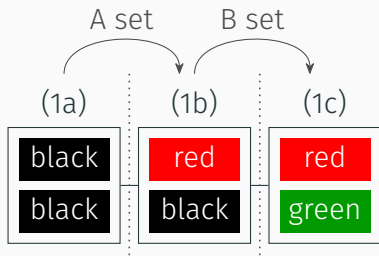


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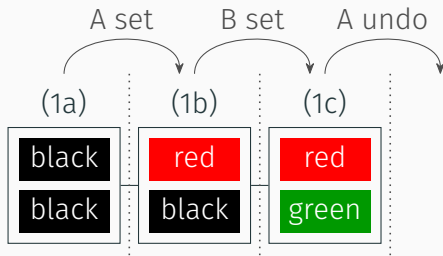


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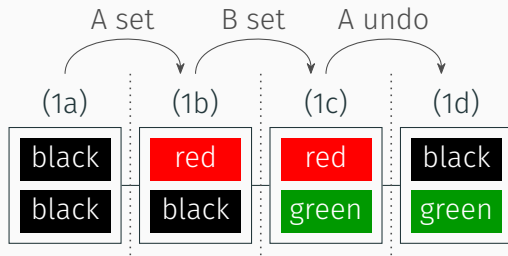


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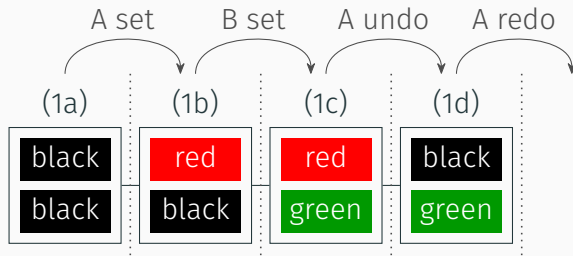


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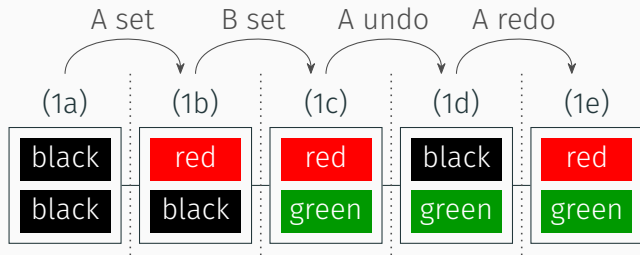


Figure 1: Canvas with two replicated registers.

(2a)

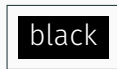


Figure 2: Canvas with one replicated register.

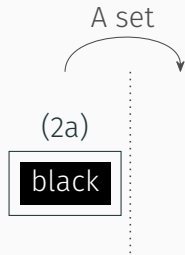


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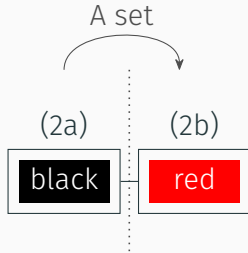


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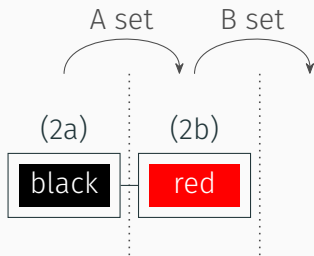


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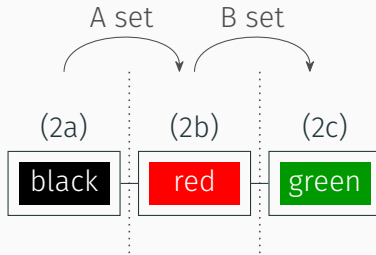


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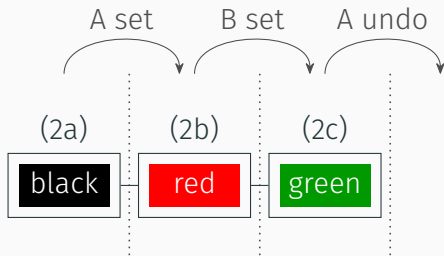


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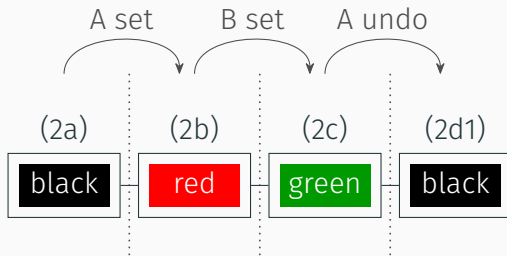


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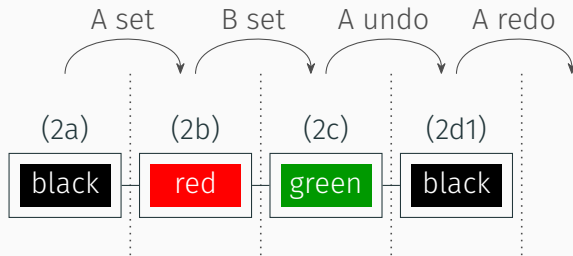


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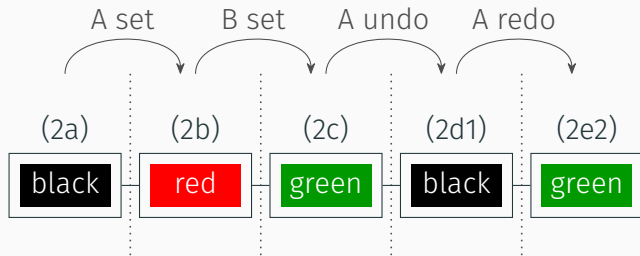


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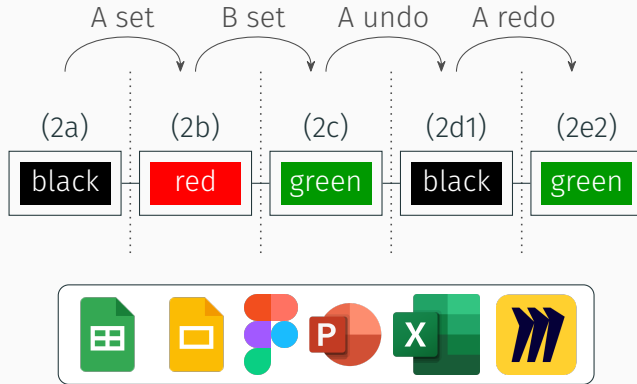


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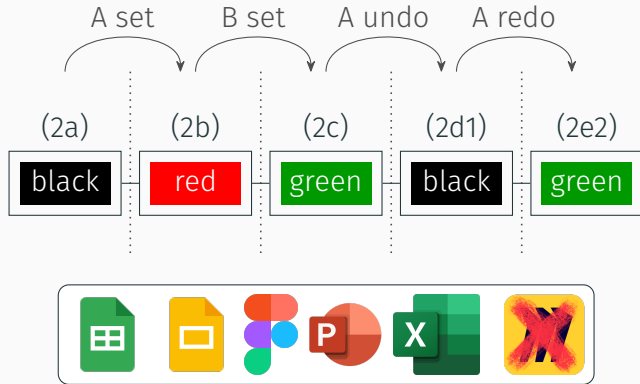


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Why Replicated Registers, if Automerge is a JSON CRDT?

Undo and Redo Support for Replicated Registers

Leo Stewen

Technical University of Munich (TUM)

Martin Kleppmann

Technical University of Munich (TUM)

Abstract

Undo and redo functionality is ubiquitous in collaboration software. In single user settings, undo and redo are well understood. However, when multiple users edit a document,

not match the behavior of current mainstream applications as detailed in Section 2. However, the algorithms of mainstream applications have not been published or analyzed in research literature and we believe that their semantics are more in line with user expectations.

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```
{  
  A: a,  
  B: [b1, b2]  
}
```

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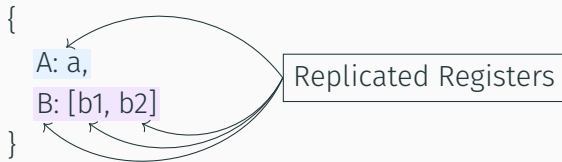
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Edge Cases to Consider (1)

Register: [■]

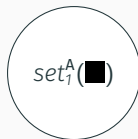


Figure 3: Undo of a merge op.

Edge Cases to Consider (1)

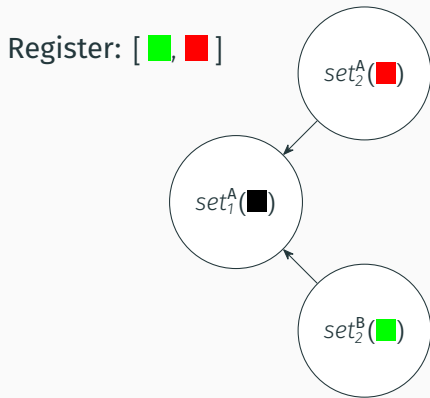


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Edge Cases to Consider (1)

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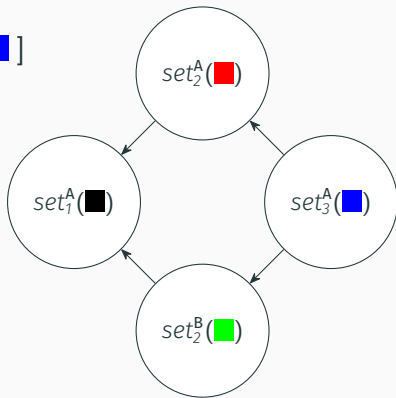


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Edge Cases to Consider (1)

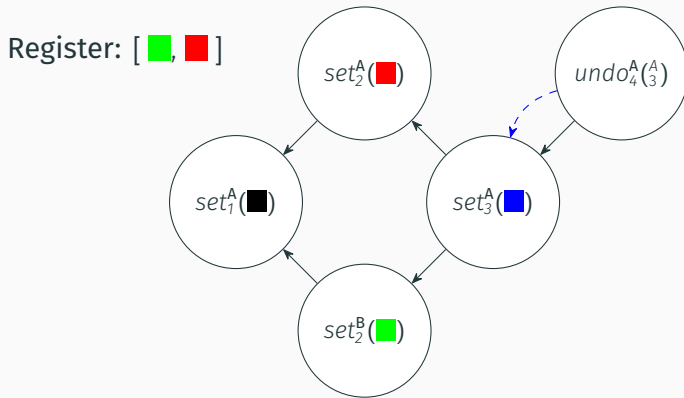


Figure 3: Undo of a merge op.

Edge Cases to Consider (2)

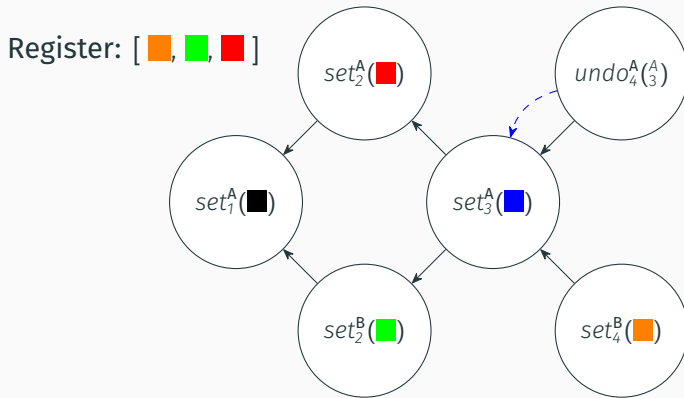


Figure 4: Concurrent undo and set op.

Edge Cases to Consider (3)

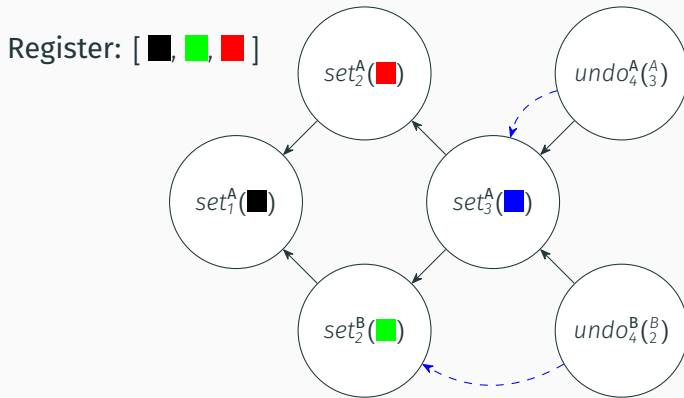


Figure 5: Concurrent undo ops.

Edge Cases to Consider (4)

Register: [■]

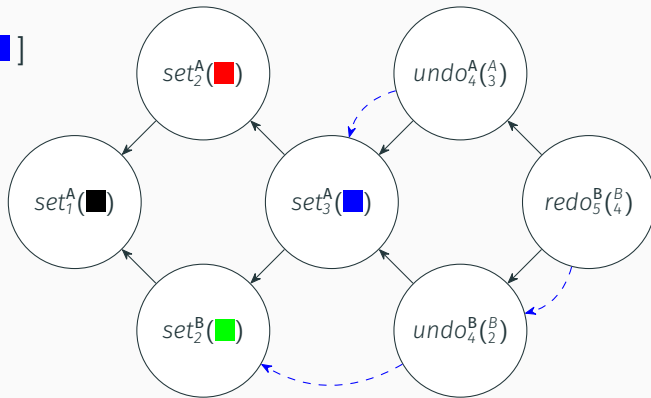


Figure 6: Redo restores state prior to its corresponding undo.

Constant Runtime for Common Editing Scenarios

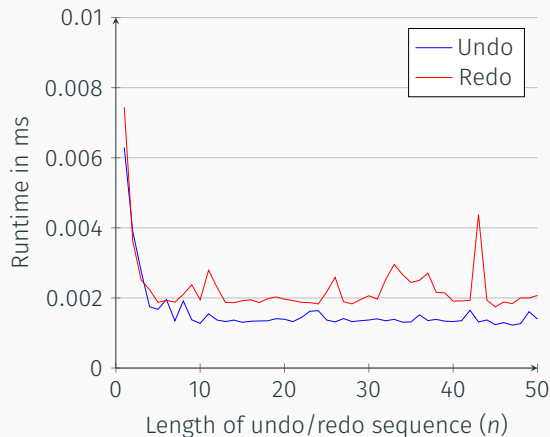
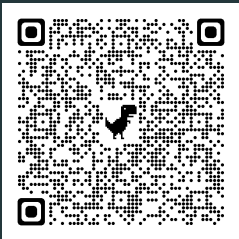


Figure 7: Runtime of the last undo/redo operation in a sequence of n consecutive undo/redo operations.

Questions? Feedback?

Reach us at
`lstwn@mailbox.org`
`liangrun.da@tum.de`
`martin@kleppmann.com`



References

- [1] W. Yu, L. André, and C.-L. Ignat, **“A CRDT supporting selective undo for collaborative text editing,”** in *15th IFIP WG 6.1 International Conference on Distributed Applications and Interoperable Systems*, ser. DAIS 2015, Springer LNCS volume 9038, Jun. 2015, pp. 193–206. DOI: [10.1007/978-3-319-19129-4_16](https://doi.org/10.1007/978-3-319-19129-4_16).

Backup Slides

(1a)

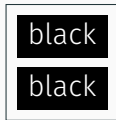


Figure 8: Canvas with two replicated registers.

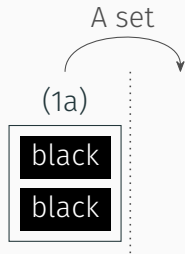


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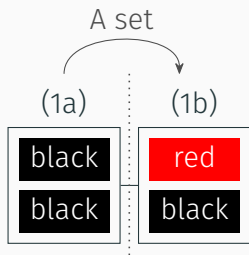


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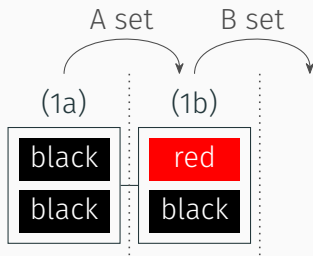


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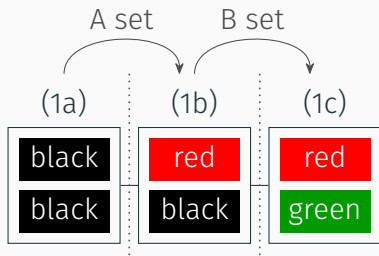


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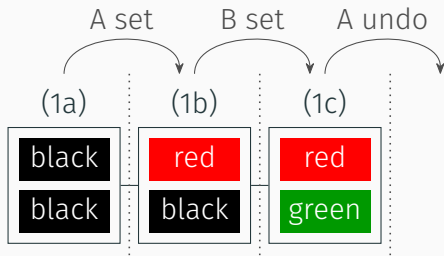


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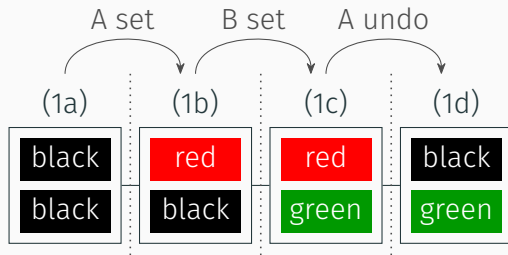


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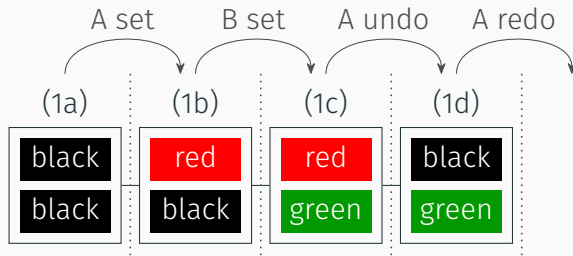


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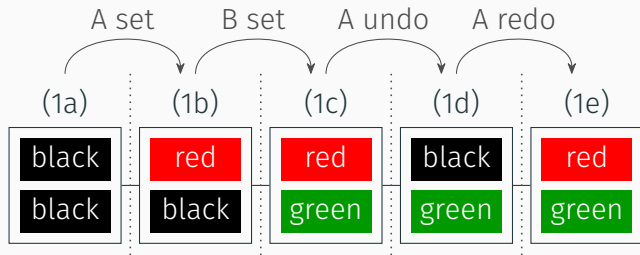


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(2a)

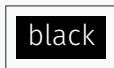


Figure 9: Canvas with one replicated register.

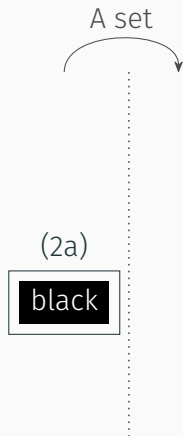


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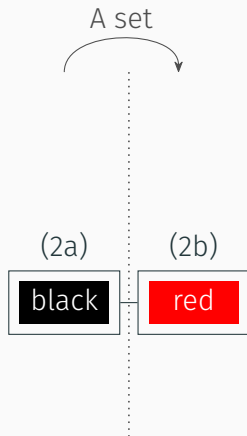


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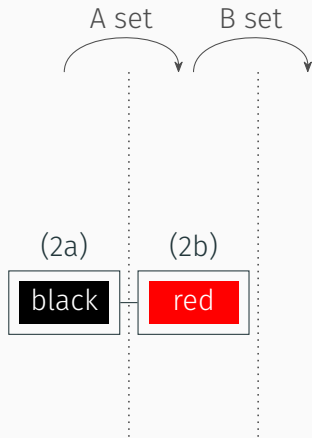


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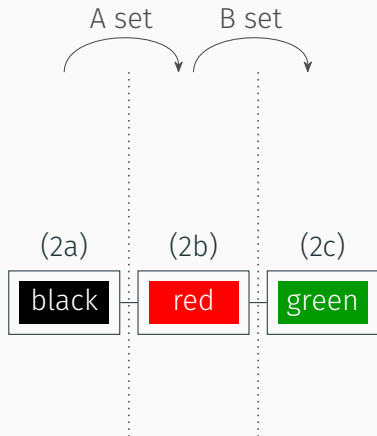


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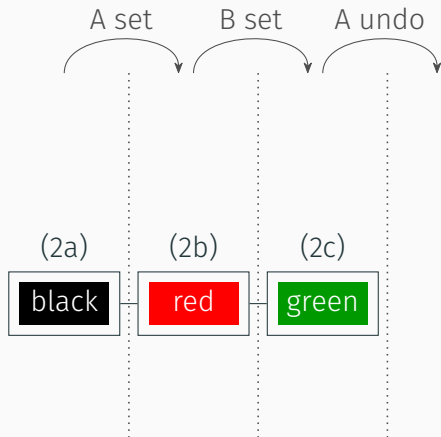


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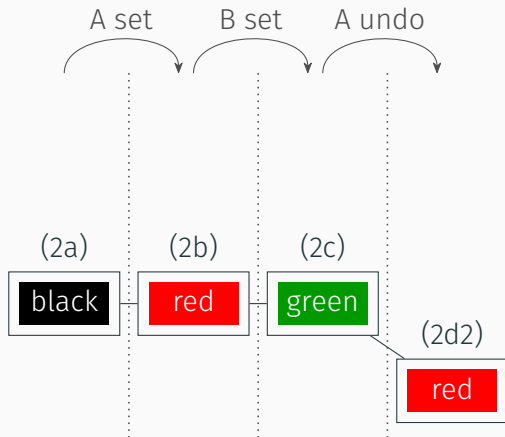


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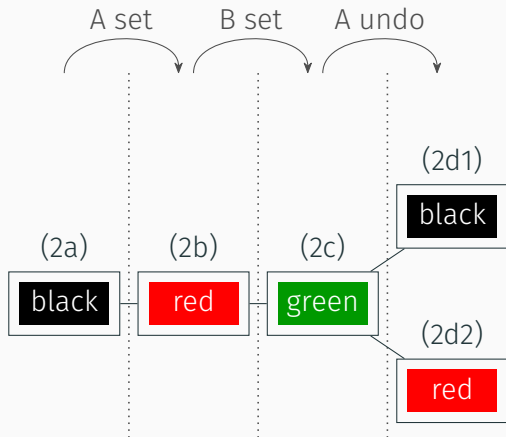


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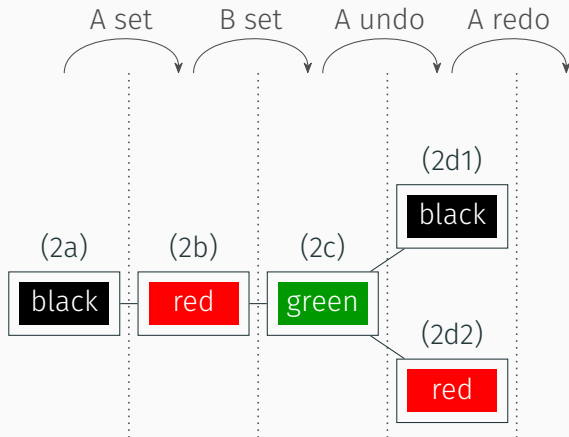


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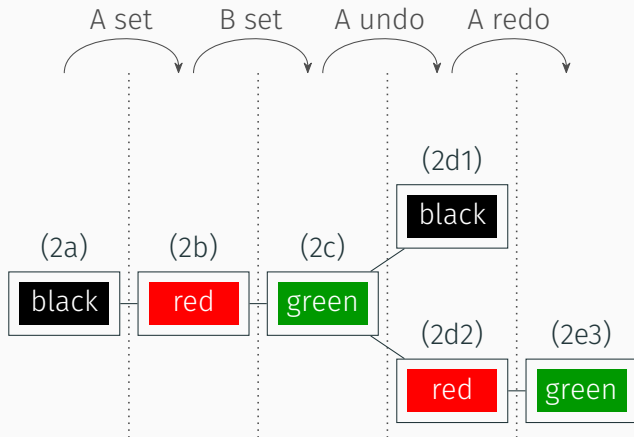


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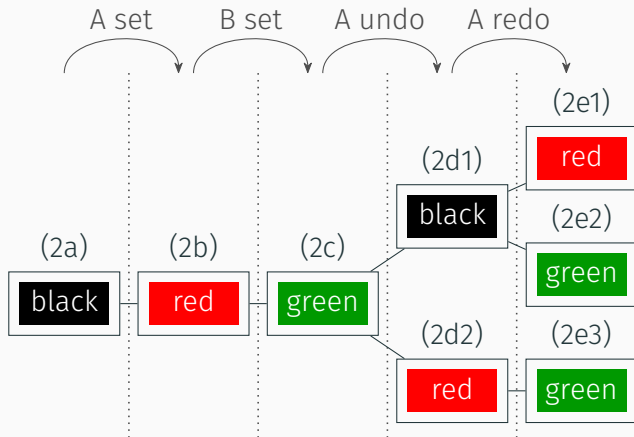


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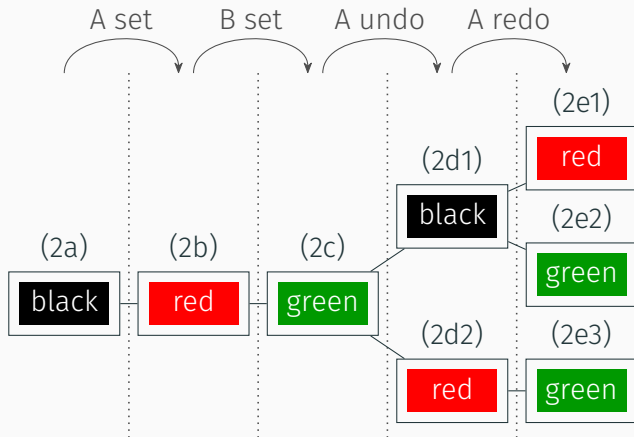


Figure 10: Canvas with one replicated register.

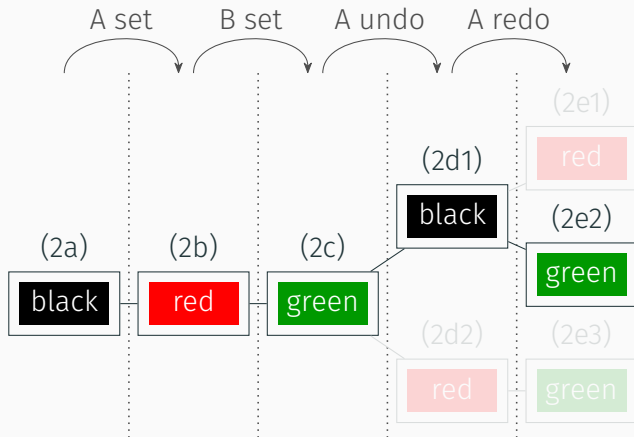


Figure 10: Canvas with one replicated register.

Register: [■]



Figure 11: Local vs global undo.

Illustration

Register: [■]

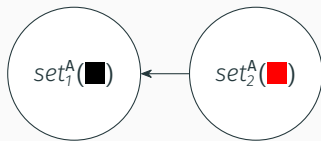


Figure 11: Local vs global undo.

Illustration

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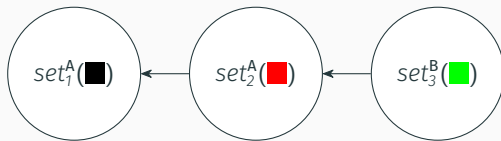


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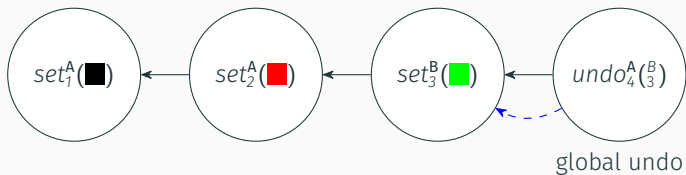


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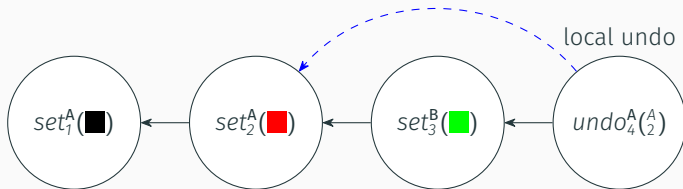


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Register: [1]



Figure 12: An operation history of a single register with undo and redo.

Register: [2]



Figure 12: An operation history of a single register with undo and redo.

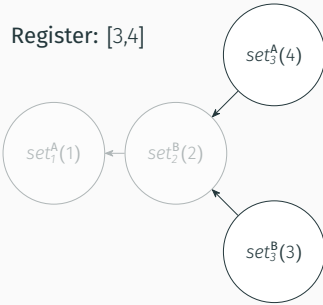


Figure 12: An operation history of a single register with undo and redo.

Register: [5]

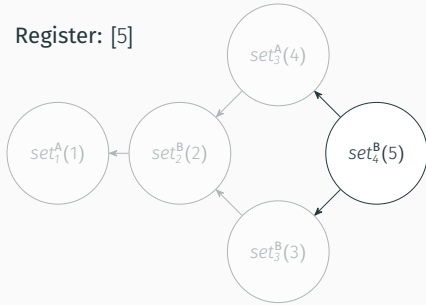


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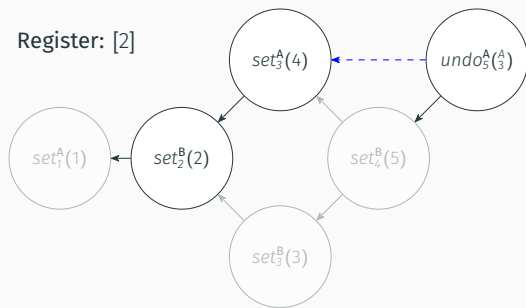


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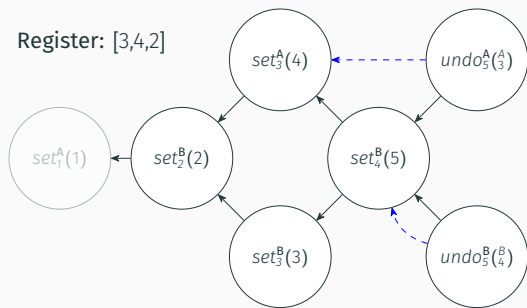


Figure 12: An operation history of a single register with undo and redo (backlink).

Register: [2]

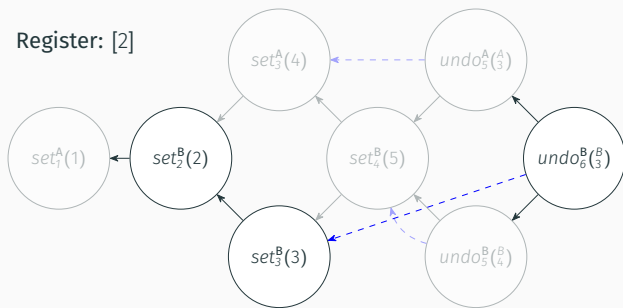


Figure 12: An operation history of a single register with undo and redo.

Register: [6]

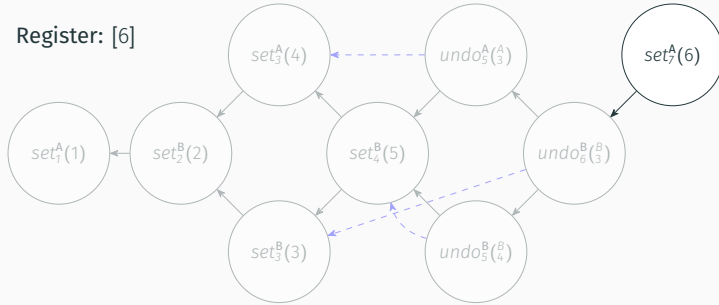


Figure 12: An operation history of a single register with undo and redo.

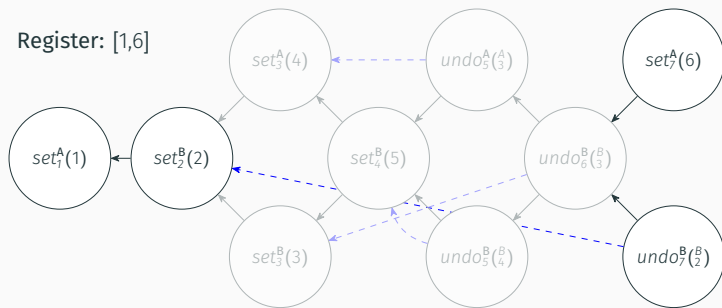


Figure 12: An operation history of a single register with undo and redo.

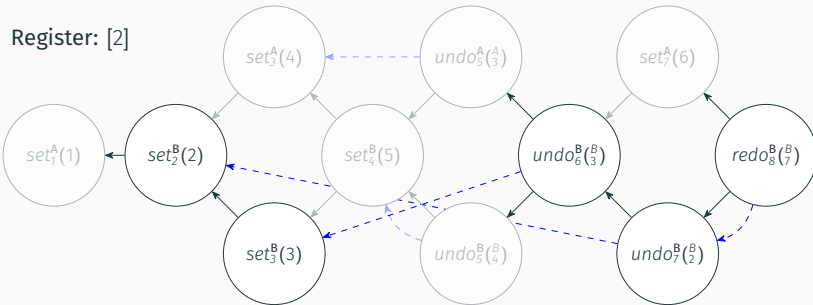


Figure 12: An operation history of a single register with undo and redo.

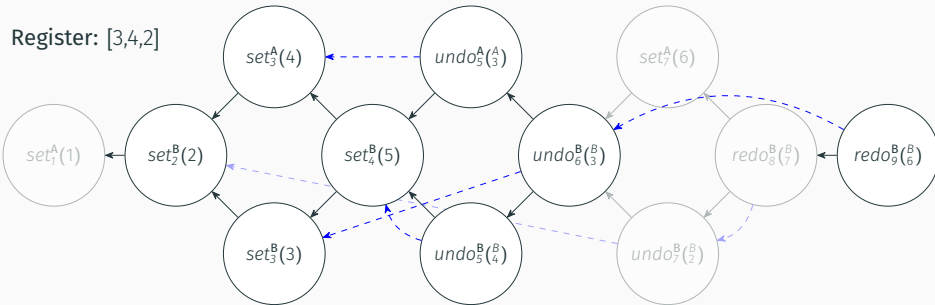


Figure 12: An operation history of a single register with undo and redo (to undo).

Register: [5]

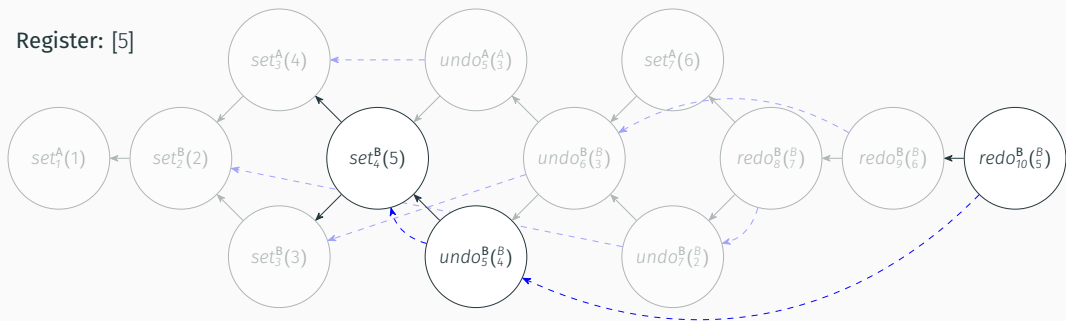


Figure 12: An operation history of a single register with undo and redo.

Degenerate Editing Scenario



Figure 13: Sequence of alternating undo-redo operations.

Degenerate Editing Scenario

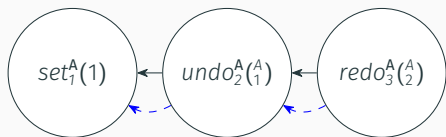


Figure 13: Sequence of alternating undo-redo operations of length 1.

Degenerate Editing Scenario

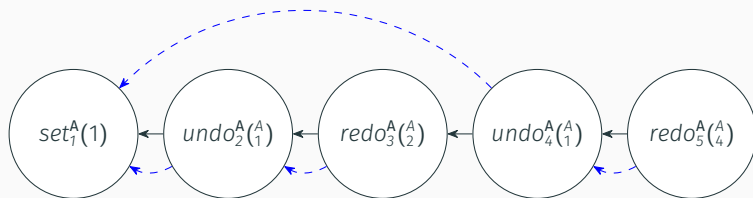


Figure 13: Sequence of alternating undo-redo operations of length 2.

Degenerate Editing Scenario

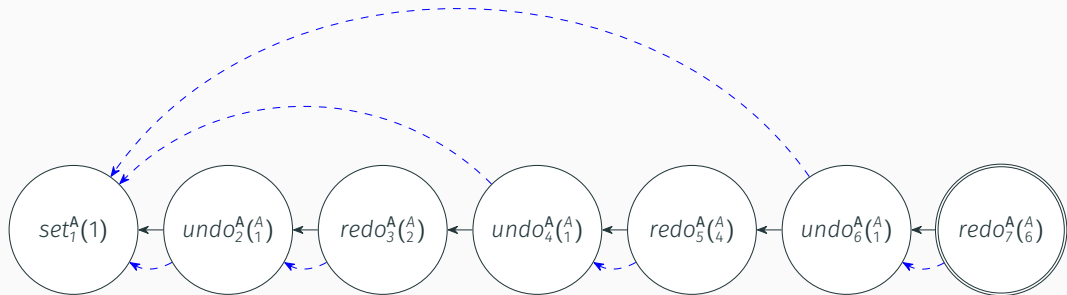


Figure 13: Sequence of alternating undo-redo operations of length 3.

Linear Runtime for Impractical Scenarios

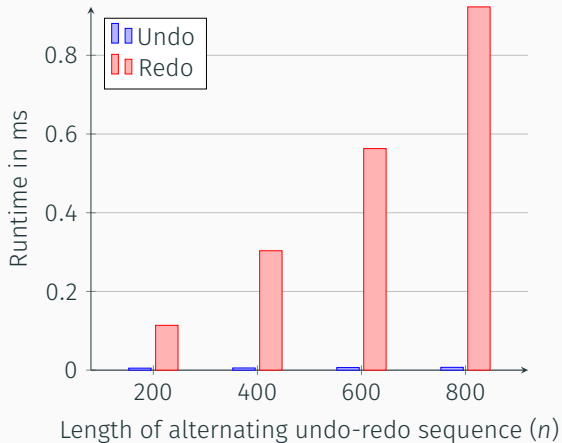


Figure 14: Runtime of the last undo/redo operation in a sequence of alternating undo-redo operations of length n .

A Taxonomy of Undo Behavior

Order \ Origin	Generating Replica	Any Replica
Reverse Chronological	local undo	global undo
Selective	revert ¹	

¹often called *selective undo* in the literature [1]

Undo Kinds in a Collaborative Setting

